Proposed ADS-B MASPS Revisions: Intent Information Broadcast
RTCA SC-186, WG-6
Version 2.0, September 2001

1. Executive Summary: Proposed Intent Changes for DO-242A

WG-6 of SC-186 is currently preparing Revision A changes to the ADS-B MASPS for balloting in the near future. One of the major changes proposed for Revision A is a significant restructuring and expansion of the Intent parameters for future ADS-B systems. This document summarizes the reasons for the proposed Intent changes and provides a detailed overview of the proposed changes to DO-242, for critical review and comment prior to SC-186 balloting and adoption of DO-242A.

There are three primary changes proposed for Intent broadcast with DO-242A ADS-B systems:

- Implementation of Target State Reports for broadcasting current flight segment target states, i.e. target altitude and target heading / track angle,
- Adoption of a broader definition of Trajectory Change Points which includes 2-D RNAV waypoints, 3-D and 4-D trajectory change points under DO-242, and level-off changes in vertical transitions,
- Implementation of Trajectory Change Reports for broadcasting successive flight segment parameters and trajectory change points. (Trajectory change reports are the DO-242A equivalent of next TCP and TCP+1 reports in DO-242, but with an expanded report format for more generic TCP's, and capability for transmitting up to four TCP's.)

Target state reports provide intent information on autopilot target states such as the current or next intended aircraft level-off altitude, i.e. target altitude, and information on directional intent expressed as a target heading angle relative to the air mass, or as a target track angle relative to an inertial or ground reference frame. These parameters reflect short term tactical intent and are typically input by the pilot, e.g. as selected altitude for limiting a descent or climb transition, or as selected heading or track when flying in a tactical, non-automated flight mode. Target altitude and target heading can also refer to the next intended targets flown by an autopilot in more automated modes such as RNAV and FMS modes, or as an input constraint to hold and maintain the current altitude or heading states.

The Trajectory Change Point definition in DO-242 was changed to accommodate a greater range of intent information, and to better reflect operational use and capabilities of existing and future aircraft avionics. The proposed Trajectory Change Reports allow for much greater flexibility in specifying intent information than the TCP's in DO-242, and provide a more comprehensive report structure for development and evolution of future ADS-B applications, e.g. trajectory conformance monitoring. Trajectory change reports include new parameters such as TCP Type to interpret the trajectory segment and change report data, and new parameters such as track-to-TCP, track-from-TCP, and turn radius as needed for trajectory segment predictions, e.g. for representing Fly-By turns consistent with FMS data outputs.

2. Introduction

The reason for considering broadcast of Intent information in ADS-B systems is to extend the domain of predictability of aircraft trajectories beyond short term extrapolations using current aircraft position and velocity states. Most current ADS-B applications under development only require state vector data. However, future applications of ADS-B could require intent information to extend lookahead time for trajectory predictions beyond the current flight segment, or as a means of enhancing integrity of extrapolated path predictions. Proposed air-air applications of intent information include airborne separation planning where more than a few minutes lookahead time is desirable for conflict detection and conflict prevention, and conflict resolution, where broadcast of intended resolution maneuvers may be important for situation awareness of all nearby equipped aircraft. ADS-B intent information is also proposed to enable advanced air-ground applications such as sequencing and merging of terminal area flow streams, and use of precision trajectory separation concepts for aircraft arrival and departure flows in congested airspace.

The current ADS-B MASPS specify only a limited range of intent information, i.e. the use of 3-D and 4-D TCP's as endpoints of the current and next flight segment, respectively. Several reasons have been advanced for expanding the use of intent beyond that in the current MASPS:

(1) ADS-B Intent should better reflect the operational capabilities of existing and future aircraft avionics systems, i.e. to represent autopilot target values when flying in lesser automated tactical modes, and to include a wide range of aircraft automation systems ranging from current 2-D RNAV systems to existing and future FMS based precision RNP RNAV systems.

(2) The current ADS-B TCP's need revision to reduce ambiguity in representing and predicting flight trajectories. One problem with the current MASPS is that TCP's alone do not adequately describe either the current intended trajectory segment, or the intended trajectory change at the endpoint TCP.

(3) ADS-B systems need expansion to better reflect longer term intent, i.e. beyond that represented by next and next+1 TCP's. Some operational concepts advanced for ADS-B implementation could require trajectory prediction times in excess of ten minutes lookahead or longer. Moreover, trajectory changes may occur quite frequently in the terminal area and more TCP's are required than in en-route applications for short term separation and flow planning.

The proposed ADS-B Intent revisions summarized in this document address the above issues.

The proposal summarized here is based on inputs from several SC-186 groups and on inputs from European standards bodies, with substantial filtering and harmonization of inputs. The resulting proposal is intended to be a basis for current MASPS implementation, and to serve as an incremental basis for future development of ADS-B applications.

3. Scope of Revision A Intent Proposal

One of the challenges in developing and evolving Intent information for ADS-B, is that most current aircraft avionics, including many advanced digital FMS based systems, do not output much intent information on avionics buses for downstream use by avionics other than those directly used to communicate to the pilot or to navigate, guide, or control an airplane. In this proposal we deal with this situation two ways: (1) allowing aircraft which output some intent information to communicate such intent when appropriate through the TSR and TCR report formats, and (2) providing intent provisioning in the report formats for future evolution and implementation of more comprehensive intent data. In short, Revision A provides an incremental approach to intent broadcasting, which allows for partial broadcasting of limited intent in Revision A, with evolution to more comprehensive intent data on both an individual aircraft basis as avionics systems are upgraded, and with further intent evolution anticipated in future Revisions to the ADS-B MASPS.

The newly proposed Target State Reports allow for broadcast of next intended *Target* level-off altitude, and *Target* heading or track data used for current path guidance. Since full implementation of Target state data may depend on FMS or autopilot mode information not currently available on any avionics bus, Revision A allows for partial implementations of Target states based on information which is available for input to an ADS-B transmit system. For example, if only autopilot based Selected Altitude is available for TSR reporting, then it is allowed to broadcast such information with appropriate mode indicators, even if the next intended level-off of the aircraft may be an unknown FMS target value. However, the fact that the aircraft is only capable of broadcasting Selected altitude / autopilot modes must be transmitted, to avoid interpreting Selected altitude as the probable next level-off state.

The Trajectory Change Reports proposed for Revision A consist of a number of horizontal and vertical flight segment and TCP types which are commonly used, have standard segment and TCP parameters, and are available as potential outputs on an ARINC data bus, e.g. the 702A trajectory bus[1]. The horizontal flight segment types include Course-to-Fix (CF), Track-to-Fix (TF), and Direct-to-Fix (DF) leg types, Fly-By and Radius-to-Fix (RF) turn segments. Fly-over turns can also be modeled by appropriate use of the above leg types in conjunction with a DF flight segment to model the turn transition to a specified end-fix. The vertical flight segments include initial climb to Top-of-Climb, flight at cruise altitude to Top-of-Descent, i.e. start of the descent phase, and some level-off transitions. In addition, target altitude as the intended end of a vertical transition is allowed as a TCP. RNAV systems that only output 2-D TCP's are also allowed, i.e. the vertical TCP components are marked as not-available.

[1] ARINC 702A, Supplement 1 document descriptor goes here

Some parameters and leg types that are important for intent broadcast that are not currently available as inputs on a data bus or are not sufficiently developed are provisioned in the TSR and TCR reports, but are not fully implemented in Revision A. This includes TSR and TCP validity bits for intent reporting, altitude constraint parameters (AT and AT and Above/Below), and leg parameters such as turn radius which may not be available for some RNAV / LNAV systems. The validity bits would provide guidance system status for TSR target values, and navigation system conformance for TCP reports and are considered essential for critical separation assurance applications. Current FMS / VNAV systems provide the ability to constrain vertical trajectories to meet altitude constraints at specified waypoints or fix locations. Broadcasting of such constraints is important for predicting vertical trajectory level-offs and changes in vertical path to meet such constraints. However, these constraint points are not generally available from FMS systems, and are not available on an ARINC data bus today. Consequently, these parameters and leg types are to be provisioned for later version ADS-B MASPS adoption.

4. Short and Long-term Intent

Target State Reports (TSR's) are implemented in DO-242A in order to provide information about the aircraft's active flight segment. The *active* flight segment in our proposal refers to the current path and automation states being used for guidance and control of the aircraft. The primary elements of the TSR include the target altitude and target heading or track angle for the active flight segment. This information is called short-term intent. TSR's provide these intent elements even in cases where no TCP exists or TCP information is only partially available. Long-term intent is provided in the Trajectory Change Report (TCR).

The amount of intent information available for data exchange depends in large part on the transmitting aircraft's current operating mode and equipment. The three primary operating modes, referred to here as manual, target state, and flight plan are shown in Figure 1. With each additional outer loop, it is possible for an aircraft to communicate more information about future states and flight segments. No more than one commanded flight segment is available while operating in a target state mode. Moreover, TCP's are not relevant when the aircraft is commanded to hold its current state. In more automated flight plan operating modes, the FMS may have knowledge of multiple trajectory change points.

Most commercial aircraft have several flight modes corresponding to the active target state and flight plan operating modes shown in Figure 1. Flight modes are normally selected through the Mode Control Panel or Flight Control Unit. The pilot can engage different lateral and vertical modes concurrently, leading to different intent availability in the horizontal and vertical axes. In some aircraft, horizontal and vertical flight commands are generated manually using a flight director display mode, rather than through direct autopilot commands. In this paper we do not distinguish between flight director and autopilot modes, since airplane mode behavior cannot be differentiated from ADS-B output reports.

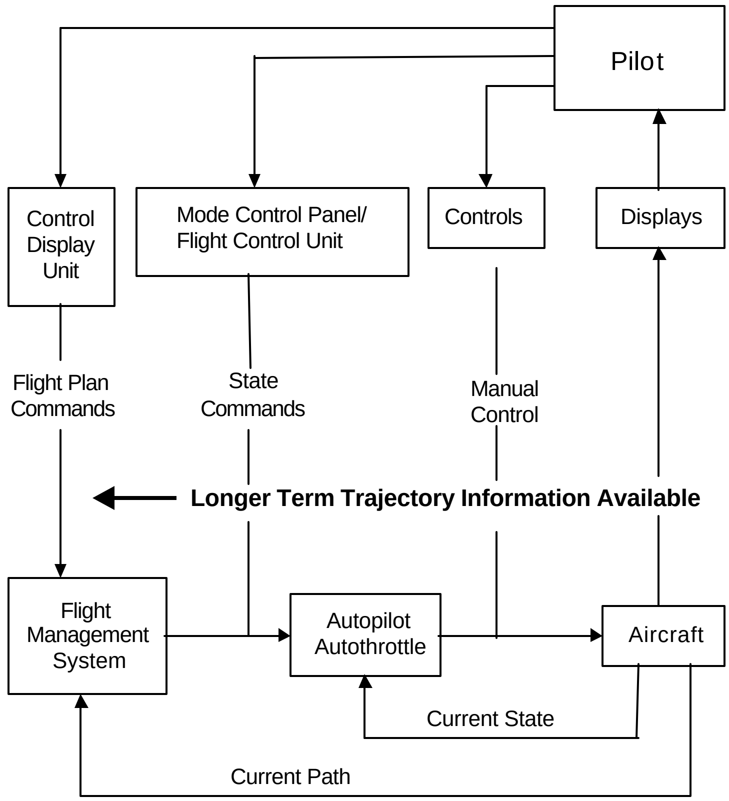


Figure 1: Aircraft Flight Modes

Figure 1 shows typical equipment available on transport category aircraft that is capable of providing the associated information. Other flight hardware may also be able to generate this information. More sophisticated equipment is needed to transmit outer loop information, although inner loop information on current target states may be difficult to transmit for older analog aircraft. A Mode Control Panel (MCP) or Flight Control Unit (FCU) is the primary interface between the pilot and autopilot when not operating in FMS automated modes. These interfaces allow the pilot to select target states such as altitude, heading, vertical speed, and airspeed. Since only the next target state is allowed in each axis, pilots often use the MCP or FCU for short-term tactical flying. Conversely, the Flight Management System (FMS) allows the pilot to select a series of target states or flight segments through a keypad-based Control Display Unit (CDU). A pilot may program an entire route complete with multiple waypoints, speed, altitude, and time restrictions, and desired speeds along different flight segments. Because the FMS allows definition of consecutive flight segments, it is frequently used for long-term strategic flying.

Complex paths may be created when an aircraft's trajectory is generated with both MCP/FCU and FMS information. Such a situation can occur when the lateral and vertical modes are controlled separately by the MCP/FCU and FMS or when an autopilot target value affects an FMS planned trajectory. The latter case is most common when the MCP/FCU selected altitude lies between the aircraft's current altitude and the programmed FMS altitude. In this case, the aircraft will level out at the selected value, i.e. selected altitude acts as a limit value on the planned climb or descent.

Both short and long-term intent information offer a potential benefit to airborne conflict management, separation assurance, surveillance, and conformance monitoring applications. Short-term intent is available in almost all operating modes, while 4D TCP's are only available when equipped aircraft are using sophisticated FMS and area navigation (RNAV) systems.

5. Target State Reports (TSR's)

Short-term intent parameters are assembled in the Target State Report, shown in Table 1. The principal elements of this report are the target altitude and target heading or track. These parameters represent the transmitting aircraft's vertical and horizontal target states and will also be included in the Trajectory Change Report if they are part of a TCP. The ***target altitude*** is the aircraft's intended level-off altitude if in a climb or descent, or the aircraft's current intended altitude if it is being commanded to hold altitude. This definition is consistent with that adopted by the European Downlink of Airborne Parameters (DAP) program.[2] Target heading is provided if the aircraft is actively being controlled to an air reference heading angle (such as a Heading Select or Heading Hold mode). Target track is used if the aircraft is controlled to a ground or inertial reference track angle, such as when flying between waypoints on a flight plan. A single bit specifies whether the aircraft is controlled to heading or track angle.

Table 1: Target State Report

Element #	Contents
1	Target Altitude
2	Target Source Indicator (Vertical)
3	Mode Indicator (Vertical)
4	*Validity Bit (Vertical)
5	Data Available (Vertical)
6	Target Heading / Track
7	Heading / Track Indicator
8	Target Source Indicator (Horizontal)
9	Mode Indicator (Horizontal)
10	*Validity Bit (Horizontal)
11	Data Available (Horizontal)

*Space reserved for future MASPS versions

(?) Is a bit also needed to differentiate between flight level and MSL altitudes ?

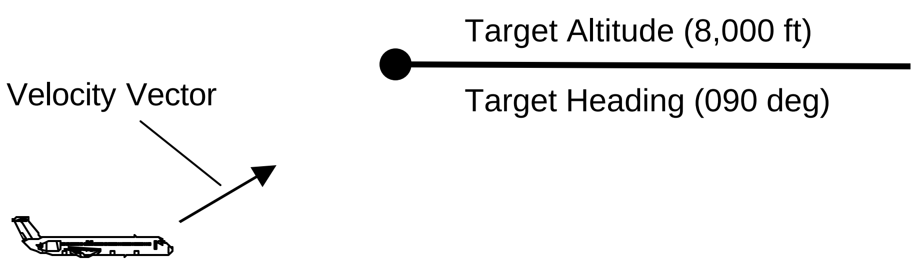
Horizontal and vertical target source indicators describe the aircraft system providing the corresponding target state. Options include the FMS, MCP or FCU selected values, or holding the aircraft's current state. In cases where the aircraft is acquiring a target altitude common to the MCP/FCU and FMS, the target source indicator should declare the target to be the former, e.g. MCP selected altitude rather than an FMS target altitude since MCP selected altitude has limiting authority over the FMS altitude.

Horizontal and vertical mode indicators provide status information on whether the aircraft is <u>acquiring</u> (transitioning toward) the target state or is <u>capturing or maintaining</u> the target. These parameters are expected to increase integrity of predicted trajectory changes and to be useful for trajectory conformance monitoring.

Future space is reserved for horizontal and vertical validity bits. These bits would provide indications of pilot or autopilot conformance to target values. Guidance validity bits for vertical and horizontal target states are under consideration, but cannot be implemented in Revision A due to data source availability issues. These bits would determine whether the aircraft is being controlled in the direction of its flight director or autopilot command.

Horizontal and vertical data availability bits indicate that target heading/track and target altitude are being reported and data reports are filled with currently relevant information.

Consider the example shown in Figure 2. An aircraft climbs at constant vertical speed toward the MCP/FCU selected altitude of 8,000 ft while flying a constant 090 heading. TSR values are provided in Table 2. Both of the targets are resident in the MCP, as indicated by the target source indicators. The mode indicators show that the aircraft is maintaining the target heading and is acquiring, but has not yet captured, the target altitude. The target heading and target altitude are available and considered reliable, as provided by the availability indicators.



<u>Figure 2:</u> Constant Vertical Speed Climb at Constant Heading to MCP/FCU Selected Altitude

Table 2: Target State Report for Figure 2

Element #	Contents
1	8,000 ft
2	MCP/FCU
3	Acquiring
4	*
5	Available
6	090 deg

7	heading
8	MCP/FCU
9	Maintaining
10	*
11	Available

In another example, the aircraft in Figure 3 is turning to join a 040 course to the ABC waypoint. It is holding its current altitude (15,000 ft). TSR values are provided in Table 3. The target source indicators show that the target track comes from the FMS, while the target altitude is the MCP selected altitude. The aircraft is acquiring the horizontal target and maintaining the vertical target. Mode indicators show that horizontal and vertical target information is available.

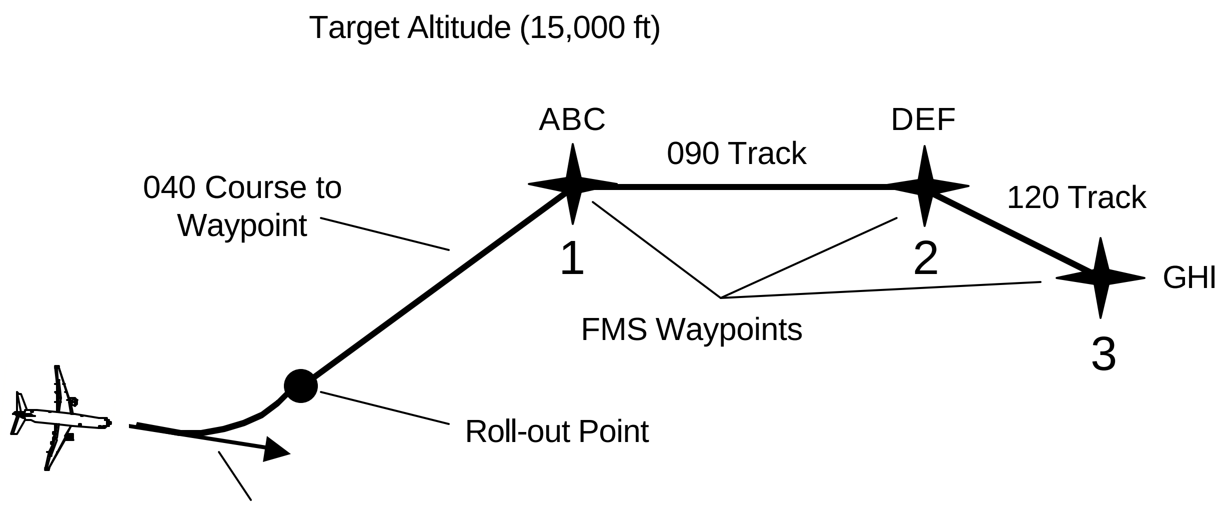


Figure 3: Intercept Course to FMS Flight Plan at Constant Altitude

Table 3: Target State Report for Figure 3

Element #	Contents
1	15,000 ft
2	MCP selected altitude
3	Capture/Maintaining
4	*
5	Data Available
6	040 deg
7	track
8	FMS
9	Acquiring
10	*
11	Data available

As described above, the target altitude and target heading/track provide horizontal and vertical target states for the active flight segment. Information subsets are allowed for aircraft incapable of providing these target states. MCP/FCU selected altitude and selected heading may be used in place of target altitude and target heading/track, respectively. Likewise, aircraft equipped with only an RNAV system may provide the RNAV track in place of the target heading. Capability class codes are implemented in DO-242A in order to distinguish between these information subsets. Intent information from an aircraft using one of these subsets may not represent the next intended horizontal or vertical target, since only partial intent is conveyed.

In order to provide a target state value, aircraft must be equipped with an autopilot or flight director that controls the axis consistent with the target value. The flight director must be on or the autopilot engaged while target state values are broadcast.

6. Trajectory Change Point (TCP) Definition

Further investigation into the many types of TCP's that can occur along an operational trajectory has led to a proposed TCP definition change for DO-242A. The current definition (DO-242 p. 39) only accommodates TCP's at a known 3D position in space. Although a 3D location is known for FMS waypoints, many flight segment changes do not occur at a known point. For example, an aircraft may be climbing in a constant vertical speed mode towards a target altitude (Figure 2). In this case, the aircraft may not take actual wind conditions into account when predicting the level-off location. Level-off prediction in a climb may also depend on changing aircraft performance. These uncertainties make it difficult to predict an accurate 3D intercept point. An analogous lateral situation may occur when an aircraft flies at constant heading to intercept a flight plan route. The intercept point is also dependent on wind parameters that may not be accurately known for intercept predictions. To account for these uncertainties, the following TCP definition is proposed: "<u>A Trajectory Change Point may be described as a 3D location or interception of a 2D plane with the aircraft's velocity vector where the current aircraft trajectory is intended to change</u>."

Examples of TCP's under this definition include 2-D routing changes, the start and end points of a specified turn transition, FMS predicted Top of Climb and Top of Descent points, and target altitudes such as MCP selected altitude when currently in climb or descent transitions. A full list of TCP types included in Revision A is provided in Section 9. Future revisions may add additional TCP types that meet this definition.

In addition to TCP's, points involving an altitude constraint (AT, AT or ABOVE, or AT or BELOW) are provisioned for future revisions into the Trajectory Change Report, even if they do not involve a trajectory change. These points influence trajectory predictions even if no level-off occurs at the altitude constraint, and provide value for conformance monitoring applications.

7. Command and Planned Trajectories

Two path definitions are essential in our proposal for describing an aircraft's intended trajectory. The *command* trajectory refers to the path the aircraft will fly if the pilot does not engage a new flight mode nor change the targets for the active or upcoming flight modes. The command trajectory may include multiple flight mode transitions. Changes to the command trajectory normally result from a pilot input. However, a non-programmed mode transition may also occur that causes the aircraft to leave the command trajectory, e.g. reversion to speed priority on descent if the intended vertical path results in an over-speed condition.

The *planned* trajectory includes intent information that is conditional upon the pilot engaging a new flight mode. Without pilot input, the aircraft will only fly toward the command trajectory targets.

Figure 4 illustrates the difference between the command and planned trajectories for a simple descent scenario. In this case, the aircraft is flying a lateral and vertical FMS path that includes an altitude restriction at the End of Descent (E/D). The MCP/FCU selected altitude lies between the aircraft's current altitude and the E/D. Assuming the pilot doesn't change the aircraft's flight mode or targets, the aircraft will fly on the FMS descent path until reaching the selected altitude and then level off. This path is the command trajectory. If the pilot resets the MCP target below the E/D altitude prior to reaching the selected altitude, the aircraft will continue to fly along the FMS descent path and will level out at the bottom of descent. The programmed FMS path beyond the selected altitude represents a planned trajectory. Typically, selected altitude represents an ATC clearance altitude. In this case, the pilot may choose to fly directly to the end of descent as soon as a clearance to the planned altitude is received.

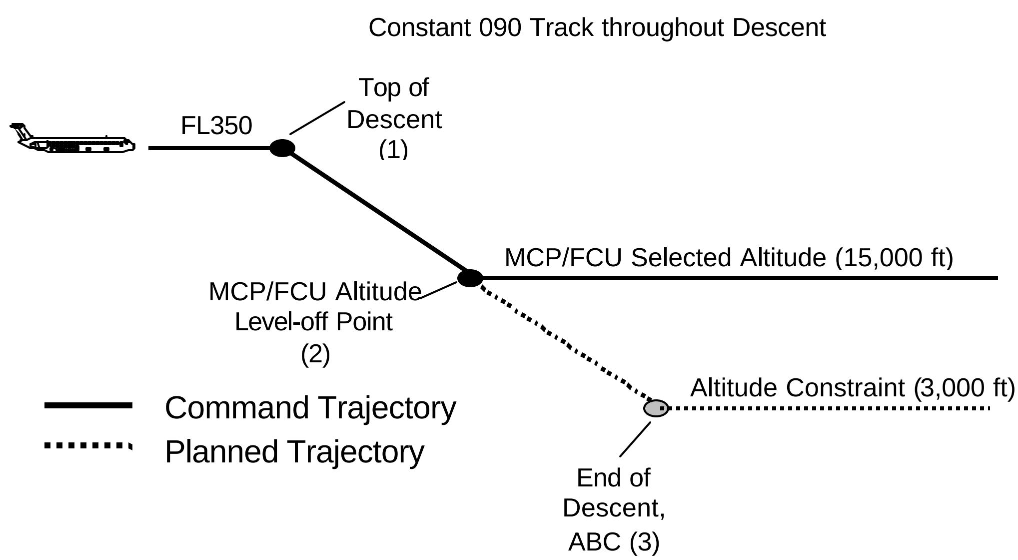


Figure 4: FMS Descent Showing Command and Planned Trajectories

These trajectory definitions are also expandable to aircraft sending intent information from non-FMS flight planning systems. For example, a LORAN or GPS navigation system on a general aviation airplane can be programmed to contain multiple waypoints. This path represents a planned lateral trajectory. It does not guarantee that the aircraft will fly that path, but represents information relevant to the pilot's long term plan.

Both the command and planned trajectories may provide useful information for separation assurance and flow management applications, respectively. In order to use this information effectively, the receiving system must be able to clearly delineate between the command and planned trajectories. This distinction is provided in the trajectory change report described below.

8. Trajectory Change Reports (TCR's)

Trajectory change reports replace the TCP's defined in DO-242. They provide an expandable structure capable of describing TCP's, waypoint constraints, and the flight segments that connect them. Many additional elements have been added to the DO-242 TCP report to facilitate path re-generation, data confidence assessment, and conformance monitoring. Some of the new parameters have been added to be consistent with ARINC trajectory bus specifications as reflected in Eurocontrol ADS Requirements.[3]

Table 4 shows the TCR structure. Not all elements are fully implemented in Revision A, but are included to show planned expansion as data becomes available. TCR fields are filled based on information availability aboard the transmitting aircraft and the TCP type.

Table 4: Trajectory Change Report

(?) Reorder the TCR fields by horizontal and vertical data fields?

Element #	Contents
1	TCP Type (Horizontal)
2	TCP Type (Vertical)
3	Latitude
4	Longitude
5	Altitude
6	Time to Go (TTG)
7	*Altitude Constraint Type
8	*Altitude Constraint Validity
9	Turn Radius
10	Track to TCP
11	Track from TCP
12	*TCP Validity (Horizontal)
13	*TCP Validity (Vertical)
14	Command/Planned (Horizontal)
15	Command/Planned (Vertical)
16	Data Available (Horizontal)
17	Data Available (Vertical)

*Space reserved for future MASPS versions

The TCP type fields in elements 1 and 2 specify the flight segment and endpoint change type. Both a horizontal and a vertical TCP type are included to aid interpretation of the data elements for constructing path segments. In addition, it is feasible to have both a routing change and a vertical change or constraint at the same waypoint. The TCP type fields specify the way that the data received is to be interpreted, e.g. which elements are required for constructing the flight segment and endpoint conditions. Example TCP types are fly-by waypoint, direct-to-fix, and RF leg (lateral cases) and top of climb, top of descent, and level-off (vertical cases). Section 9 describes the TCP types included in Revision A. Other types, including waypoint constraints, may be added to future revisions.

The availability of TCR elements 3-6 depends on the transmitting aircraft's operating mode and equipment capability. These elements are provided if they are associated with a known waypoint or can be estimated by the FMS. These elements will have varying accuracy depending on TCP type. When using FMS lateral and vertical navigation, TCP's associated with waypoints can be estimated with high confidence. For TCP's which do not involve closed-loop control, such as top of climb, top of descent, or path intercepts, the latitude, longitude and time elements have higher uncertainty. Low integrity latitude/longitude predictions such as the "green arc" on Boeing aircraft that predicts altitude level-offs for MCP modes are not included. These predictions can vary greatly if they do not compensate for varying wind and aircraft performance

Elements 7 and 8 are provisioned for future use. These elements can be use to indicate the type of altitude constraint (at, at or above, at or below) and the transmitting aircraft's assessment of its ability to meet the altitude constraint. Altitude constraints may or may not be associated with a trajectory change point, since the aircraft may be able to comply with the constraint without changing its trajectory. Future DO-242 revisions may further expand the TCR to include speed and time constraints.

Figures 5 and 6 show the information needed for fixed radius and fly-by turns (Elements 9-11). Fixed radius turns include turn radius and start and end of turn points. Fly-by turns can also be described in this manner, however the alternate representation in Figure 6 is acceptable if the aircraft cannot provide start and end of turn points. In this case, the fly-by turn waypoint is provided, along with the track to and track from that point and the turn radius. Fly-over turns are represented in Revision A as a Direct-to transition to the specified endpoint. For other horizontal TCP's, only the track to the TCP (Element 9) is provided.

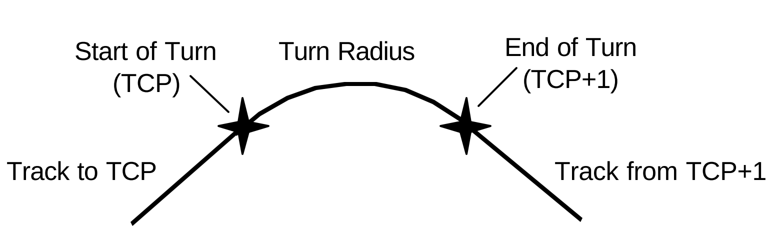


Figure 5: Fixed Radius or Fly-by Turn

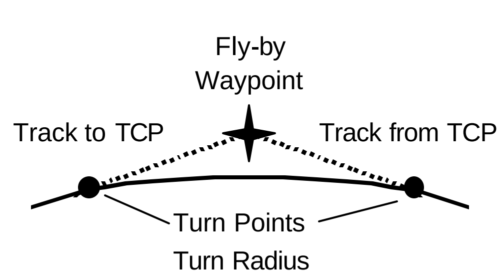


Figure 6: Fly-by Turn

Space is reserved for horizontal and vertical validity bits (Elements 12-13). These bits assess the conformance of the transmitting aircraft to its broadcast path. It is anticipated that future revisions may use horizontal and vertical RNP bounds to specify trajectory conformance. The validity bits may broadcast the ability/inability of the aircraft to conform to the specified trajectory bounds. For non-RNP aircraft, other measures of trajectory conformance may be specified.

Elements 14-15 delimit whether the flight segment and TCP is part of the command or planned trajectory (see description in Section 7). Successive TCP's or altitude constraint points that are part of the command trajectory should be ordered as they are expected to occur, e.g. by TTG. In cases where time to go cannot be determined, points having an altitude closest to the aircraft's current altitude should be placed first. If there is space available for additional points, planned TCP's can be included, but they should be placed at the end of the TCP list.

Elements 16-17 assess the availability and currency of horizontal and vertical TCP data. The associated horizontal and vertical data fields should not be used if they are reported unavailable.

Figures 3 and 4 are simple examples of horizontal and vertical FMS trajectories, respectively. The filled TCR elements corresponding to Figures 3 and 4 are given in Tables 5 and Table 6, respectively. Figure 3 shows an aircraft turning to join a 040 course to waypoint ABC, followed by two routing changes at DEF and GHI. The roll-out point is not considered to be a TCP, but is a portion of the Direct-to-ABC segment. After rolling out, it will join the FMS flight plan and fly to waypoints DEF and GHI. This example is flown at a constant altitude of 15,000 ft. All latitude and longitude fields are filled since all TCP's in this example are FMS waypoints. The aircraft is holding its selected 15,000 ft altitude, which is repeated for each TCP point. The end of the DF segment is the start of the Fly-By Turn, which is represented implicitly by the ABC waypoint and Fly-By turn radius. The straight line and turn segments for the Fly-By turns are similarly represented implicitly, reducing the number of TCP's to represent the intended path.

Table 5: Trajectory Change Report for Figure 3

Element #	Contents (TCP)	Contents (TCP+1)	Contents (TCP+2)	Contents (TCP+3)
1	DF to Fly-By	Fly-By Turn	Fly-By Turn	Fly-By Turn
2	Selected altitude	Selected altitude	Selected altitude	Selected Altitude
3	Latitude_{ABC}	Latitude_{ABC}	Latitude_{DEF}	Latitude_{GHI}
4	Longitude_{ABC}	Longitude_{ABC}	Longitude_{DEF}	Longitude_{GHI}
5	15,000 ft	15,000 ft	15,000 ft	15,000 ft
6	TTG-Turn Start	TTG-ABC	TTG-DEF	TTG-GHI
7	X	X	X	X
8	No	No	No	No
9	Radius_{ABC}	Radius_{ABC}	Radius_{DEF}	Radius_{GHI}
10	040 deg	040 deg	090 deg	120 deg

11	X	090 deg	120 deg	Track from GHI
12	*		*	*
13	*		*	*
14	Command	Command	Command	Command
15	Command	Command	Command	Command
16	Data Available	Data Available	Data Available	Data Available
17	Data Available	Data Available	Data Available	Data Available

In Figure 4, the aircraft is flying in cruise at FL350, approaching the top of descent. The FMS cruise altitude is limiting and functions as the vertical target source. It has a single FMS altitude constraint (cross ABC at 3,000 ft). The MCP/FCU altitude is set to an intermediate value of 15,000 ft. Since the aircraft respects the MCP/FCU altitude, it will level-off at 15,000 ft, given the current automation state. This path is the command trajectory. If the pilot resets the MCP/FCU altitude prior to reaching 15,000 ft, the aircraft will continue toward the FMS altitude constraint at ABC. ABC is included as a planned trajectory point. It has a known 3D location and the FMS time estimate may be provided.

Table 6: Trajectory Change Report for Figure 4

Element #	Contents (TCP)	Contents (TCP+1)	Contents (TCP+2)
1	Course-to-Fix	Course-to-Fix	Course-to-Fix
2	Top-of-Descent	Selected Altitude	End-of-Descent
3	Est	Est	Latitude_{ABC}
4	Est	Est	Longitude_{ABC}
5	FL350	15,000 ft	3,000 ft
6	TTG-TOD	TTG-MCP_ALT	TTG-ABC
7	X	X	AT
8	No	No	Yes
9	X	X	X
10	Track to T/D	Track to ABC	Track to ABC
11	X	X	X
12	*	*	*
13	*	*	*
14	Command	Command	Planned
15	Command	Command	Planned
16	Data Available	Data Available	Data Available
17	Data Available	Data Available	Data Available

"Est": Element contents filled with FMS lat/long estimates, if available.

The TCR report provides flexibility for accommodating different TCP types and varying amounts of information available onboard the transmitting aircraft. The TCR report structure shown in Table 4 represents full reporting capability. Many aircraft may not be equipped to support all of these data elements. As with TSR's, capability class codes are established to allow partial reporting. One information subset that will be allowed in Revision A is the ability to provide only 2 dimensional waypoints. Many RNAV and GPS systems only allow lateral waypoints and have no associated altitude estimate. Further information subsets are under consideration. When a partial information capability class is observed, the receiving aircraft should consider that additional non-reported TCP's may exist prior to the next reported TCP. Since only a limited number of TCP types are included in Revision A, even the most sophisticated aircraft may change trajectory at a non-reported TCP. As discussed above, future DO-242 revisions may include the capability to report waypoint constraints. Altitude constraints are likely to benefit a number of applications and space is made available for these point types in Revision A.

9. Horizontal and Vertical TCP Types

- Horizontal TCP Types
  - Straight Line (CF, TF leg types) - includes start-of-turn TCP's
  - Straight Line to Fly-By turn (CF, TF leg types)
  - Direct-to-Fix transition
  - Direct-to-Fly-By turn
  - Turn segment for Fly-By turn
  - Turn segment for Radius-to-Fix (RF) turn
- Notes on Horizontal Types, e.g. difference between CF, TF on transmit; explanation of DF leg type to model Fly-over turns, etc.
- Vertical TCP Types
  - Target Altitude (no endpoint)
  - Top of Climb
  - Top of Descent
  - Start of Level, e.g. End-of-Descent
  - Altitude Constraints (At, At & Above / Below) – Rev B Provision
- Notes on Vertical Types, e.g. target altitude could be MCP selected or cruise alt; priority scheme for alt. window constraints
- Possible future Revisions for horizontal and vertical RNP

10. **Minimum Intent Report Requirements**

a. Equipage Classes A2 and A3
   - Class A2 req'ts: target altitude plus heading and 1 horizontal TCP
   - Class A3 req'ts: class A2 plus capability for up to four TCP's

- Transmission Update Requirements – slow / fast update rate req'ts
- Max Lookahead Time Requirements – no TCP necessary when TTG > xx min.

11. Future Plans for Intent Consideration

a. Additional TSR's, i.e. target airspeed, target vertical rate / FPA
b. Special operations, e.g. on condition reports for min approach speed
c. Additional TCP leg types, e.g. holding pattern, airspeed TCP's
d. RNP based separation, i.e. addition of RNP containment parameters